CAPACITANCE-BASED PROXIMITY WITH INTERFERENCE REJECTION APPARATUS AND METHODS

The following patent is a continuation-in-part patent of U.S. patent application Ser. No. 08/193,275, filed Feb. 8, 1994, now U.S. Pat. No. 5,478,170, which is a continuation of Ser. No. 914,043, filed Jul. 13, 1992, now U.S. Pat. No. 5,305,017.

This invention relates generally to apparatus and methods for touch sensitive input devices, and more particularly, to apparatus and methods for capacitance-based touch detection wherein electrical interference is effectively rejected from the detection system.

BACKGROUND OF THE INVENTION

Numerous prior art devices and systems exist by which tactile sensing is used to provide data input to a data processor. Such devices are used in place of common pointing devices (such as a "mouse" or stylus) to provide data input by finger positioning on a pad or display device. These devices sense finger position by a capacitive touch pad wherein scanning signals are applied to the pad and variations in capacitance caused by a finger touching or approaching the pad are detected. By sensing the finger position at successive times, the motion of the finger can be detected. This sensing apparatus has application for controlling a computer screen cursor. More generally it can provide a variety of electrical equipment with information corresponding to finger movements, gestures, positions, writing, signatures and drawing motions.

In U.S. Pat. No. 4,698,461, Meadows et al., a touch surface is covered with a layer of invariant resistivity. Panel scanning signals are applied to excite selected touch surface edges so as to establish an alternating current voltage gradient across the panel surface. When the surface is touched, a touch current flows from each excited edge through the resistive surface and is then coupled to a user's finger (by capacitance or conduction), through a user's body, and finally coupled by the user's body capacitance to earth ground potential. Different scanning sequences and modes of voltage are applied to the edges, and in each case the currents are measured. It is possible to determine the location of touch by measuring these currents. In particular, the physical parameter which indicates touch location is the resistance from the edges to the point of touch on the surface. This resistance varies as the touch point is closer or farther from each edge. For this system, the term "capacitive touch pad" may be a misnomer because capacitance is involved as a means of coupling current from the surface touch point through the user's finger but is not the parameter indicative of finger position. A disadvantage of this invention is that accurate touch location measurement depends on uniform resistivity of the surface. Fabricating such a uniformly resistive surface layer can be difficult and expensive, and require special fabrication methods and equipment.

The panel of the Meadows '461 patent also includes circuitry for "nulling", or offsetting to zero, the touch currents which are present when the panel is not touched. This nulling can be accomplished while the panel operates, and allows touches which generate a relatively weak signal, such as from a gloved finger, to be more accurately determined. The Meadows '461 panel also includes circuitry for automatically shifting the frequency of panel scanning signals away from spectra of spurious signals, such as those developed by cathode-ray tube transformers, which may be present in the environment. The panel seeks to avoid interference from the spurious signals, which could happen if the frequency of scanning was nearly equal to that of the spurious signals. A microcontroller determines whether the scanning frequency should be shifted by monitoring the rate at which adjustments are required in nulling of the touch currents, as described above. The only means described for generating frequency control signals is based on this nulling adjustment.

U.S. Pat. No. 4,922,061, Meadows et al., is similar to the Meadows '461 patent in that the touch panel determines touch location based on variations in resistance, not capacitance. This is particularly evident from FIG. **2** where the resistances from edge to touch point are shown as Kx times Rx, where Kx is corresponds to the distance indicated by **76**A. The apparatus uses a measurement signal of a frequency that varies in a substantially random manner, thus reducing susceptibility to interference from spurious electromagnetic spectra.

U.S. Pat. No. 4,700,022, Salvador, describes an array of detecting conductive strips, each laid between resistive emitting strips. The finger actually makes electrical contact from an emitting strip to detecting strip. Touch location is determined from resistance variation (as with Meadows '461 and '061 above) in the strip contacted by the finger. Averages are taken of a certain number of synchronous samples. A design formula is presented to choose a sampling frequency so that it is not a multiple of the most undesired predetermined interfering signal. No suggestion is made that sampling frequency is adjusted or adapts automatically.

In U.S. Pat. No. 5,305,017, Gerpheide, touch location is determined by true capacitance variation, instead of resistance variation, using a plurality of electrode strips forming virtual electrodes. This approach eliminates the necessity of a coating having uniform resistance across a display screen. However, such a capacitance-based detection device may suffer from electrical background interference from its surroundings, which is coupled onto the sensing electrodes and interferes with position detection. These spurious signals cause troublesome interference with the detection of finger positioning. The device operator may even act as an antenna for electrical interference which may cause a false charge injection or depletion from the detecting electrodes.

Accordingly, there is a need for a touch detection system which has the following characteristics:

(1) the touch location is determined without the need of resistance variation so as to avoid the high cost of requiring uniform resistance during fabrication;

(2) the touch location is measured in a manner independent of resistance of the electrodes or their connecting wiring, thus broadening the range of materials and processes which may be used for fabrication; and

(3) electrical interference signals are rejected and eliminated from the detection system regardless of their frequency and without requiring possibly expensive nulling apparatus.

SUMMARY OF THE INVENTION

The present invention employs a touch location device having true capacitance variation by using insulated electrode arrays to form virtual electrodes. The capacitance variation is measured by means independent of the resistance of the electrodes, so as to eliminate that parameter as a fabrication consideration. The electrical interference is eliminated regardless of frequency to provide a clear detec-